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PATENT SPECIFICATION

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DRAWINGS ATTACHED

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(54) REGASIFICATION OF A LIQUEFIED GASEOUS MIXTURE

(71) We, ESSO RESEARCH AND ENGINEERING COMPANY, a Corporation duly organised and existing under the laws of the State of Delaware, United States of America, of Linden, New Jersey, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention provides a method for the regasification and pressurization of condensed low temperature gaseous mixtures by a heat integration scheme which maximizes the use of the "cold" in the liquid to be regasified and pressurized. This heat integration scheme, as opposed to the use of separate heat transfer media, results in substantial economic advantages in that more economical heat exchange equipment can be used, no separate handling facilities are needed for an intermediate heat transfer media and losses normally accompanying the use of intermediate heat transfer media are eliminated. The heat integration scheme makes possible the elimination of compressors and minimizes the pumping equipment used to increase the pressure of the regasified mixture.

The present invention relates generally to a method of heating low temperature fluids. More particularly, the process of the instant invention provides a method for heating low temperature fluids by employing a heat integration scheme which maximizes the use of the "cold" in the fluid being heated and which results in the minimization of investment and operating costs. The teachings of the instant invention are particularly applicable to the regasification of liquefied natural gas (hereinafter referred to as LNG).

Natural gas is often available in areas remote to where it will be ultimately used. Quite often the source of this fuel is separated from the point of utilization by a large body of water, in which case it may prove necessary to effect bulk transfer of the natural gas by large marine tankers designed for such transport. Under these circumstances, economics dictate that the natural gas be liquefied so as to greatly reduce its volume and that it be transported at essentially atmospheric pressure. Under these conditions the LNG is at a temperature of approximately −258°F. This temperature represents the boiling point of methane at atmospheric pressure. It is to be noted, however, that the LNG often contains amounts of heavier hydrocarbons, such as ethane, propane, butane and the like. These will vary the boiling range of the LNG so that it usually will fall somewhere between −240°F. and −258°F. However, nitrogen, which may also be present, can cause the low end of the temperature range to approach temperatures as low as −270°F.

When the LNG arrives at the point of utilization, it is in liquefied form, and it becomes necessary to regasify it before it is used as a fuel. In addition, it may be necessary to adjust the heating value of the natural gas to conform to local requirements prior to its entrance into the actual fuel distribution system. Where this is required, adjustment may be conveniently achieved by use of reforming operation of the type to be discussed hereinafter. It may also become necessary to increase the pressure of the regasified product from atmospheric pressure to the distribution pipeline pressure, which in some cases may be as high as 1000 psia.

It will be appreciated that the reconversion of the LNG to a gaseous form requires the addition of a substantial amount of heating. When heating cryogenic streams such as LNG, many problems both of an economic and technical nature are often encountered. For example, when heating such streams, direct heat exchange is only feasible with heating streams which are dry, since any moisture present would freeze out and deposit and would eventually block or plug the heat exchangers employed. Also, the least

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expensive heat sources are wet (e.g. water, steam, air and flue gas), so that problems in this area are often encountered. In the past problems of this nature have been solved by using a separate intermediate heat exchange fluid contained in a closed cycle or the like. The function of this type of intermediate fluid system is to absorb heat from a hot wet heat source and inject it to the cold LNG stream. However, there are numerous economic disadvantages which accompany the use of such a system. For example, heat exchanger area requirements are in effect doubled since the number of needed exchangers are usually as high. Furthermore, separate facilities are required to store, handle and possibly produce the separate intermediate exchange fluid.

In contrast to the above, the teachings of the instant invention provide a method for heating cryogenic fluids such as LNG, which avoids the above mentioned difficulties. Thus, utilization of the method to be herein described in further detail results in substantial reductions in heat exchange costs and eliminates need for separate handling facilities. Also the need to make up losses in the amount of intermediate heat exchange media is avoided.

According to the present invention, the above highly desirable results are achieved by using recycled process streams in place of an intermediate heat exchange fluid. In a preferred embodiment of the invention, the regasification of liquified natural gas is accomplished in combination with a reforming operation of a type known in the art and to be hereinafter discussed. In a preferred embodiment of the instant invention a cold liquid LNG stream is warmed by being passed through a series of heat exchangers, which exchangers serve to condense overhead vapors from a flashing drum and a distillation column (the column serving to effect the separation of C_3+ constituents from the lighter constituents of the natural gas). Upon its passage through this series of heat exchangers, the entering LNG is then heat exchanged with a portion of the bottoms from a second flashing drum and then enters the first flashing drum as feed. A portion of the bottoms from the second drum is passed in heat exchange with one or more hot streams available from the reforming operation. The overhead from the second flashing drum and the remaining portion of the bottoms product from said drum are combined and passed to the fractionating column. The bottoms of this column, comprising C_3 and heavier hydrocarbons, are fed to the reforming operation, as will be further discussed hereinafter. The top products from the tower are passed in heat exchange with the LNG as hereinbefore indicated and the condensed liquids are recycled into the upper region of the column. The uncondensed vapors are also passed in a second heat exchange with the LNG (which serves to warm the latter) and are then pumped up to suitable pipeline pressures. Following this increase in pressure, these materials are passed in heat exchange with the overhead vapors from the first drum and then are fed into a suitable gas distribution system.

Accordingly, the object of the invention is to provide an efficient method for heating a cold fluid without the need for separate intermediate heat exchange media.

Another object is to provide a system which allows the use of more economical heat exchange equipment and no separate intermediate heat transfer fluid facilities, thereby effecting substantial economies in equipment cost, uses lower pressure heat exchange equipment in the initial LNG heating, and which requires fewer pumps needed to effect the desired pipeline pressure and minimizes operating costs in bringing the LNG from atmospheric pressure to the relatively high pipeline pressure.

Reference will now be made to the accompanying drawings in which the single figure is a flow diagram illustrating a process according to the present invention.

Referring to the drawing, a stationary insulated storage tank 2 receives the LNG at atmospheric pressure from a tanker (not shown). The LNG in tank 2 will normally have a temperature of about −240°F. to −260°F. and may have, for example, the composition ranges shown in Table I.

TABLE I

Constituent	Mole %
C_1	60 to 70
C_2	15 to 25
C_3	8 to 15
C_4	2 to 4
C_5	0 to 1
C_6+	0 to 1

The LNG from tank 2 is fed through the line 3 into pump 4 wherein its pressure is increased to from about 14.7 to about 500 and preferably about 450 psia. The pump 4 causes the pressurized LNG stream to flow via the lines 6, 12, 14 and 18 through a series of heat exchangers 8, 10, 16 and 20, to be further discussed hereinafter. Upon exiting from exchanger 20 via the line 22, the LNG stream has been heated to a temperature in the range of −30°F. to −70°F. and preferably around −58°F. The heated LNG stream is then fed into a first flashing drum 24. Drum 24 may be operated in the range of 300 to 500 psia with a preferable range of from about 350 to about 400 psia. The flashed vapors from drum 24 will be mostly methane and will have a composi-

tion range such as shown in Table II. This composition will, of course, depend on the composition of the initial feedstock and the exact temperature and pressure of the drum 24.

TABLE II

Constituent	Mole %
C_1	80 to 95
C_2	5 to 15
C_3	0 to 3
C_4	0 to 1
C_5	0 to .1
C_6	0

From drum 24 these vapors are fed via conduit 26 through heat exchanger 10. A portion of the vapors from drum 24 branch off into conduit 30 and are fed through heat exchanger 32. Vapors in exchanger 10 serve to warm the entering LNG in line 12. The splitting of the overhead from flashing drum 24 into conduits 26 and 30 insures that the temperature approaches in heat exchangers 10 and 32 do not fall below allowable limits. Upon exit from exchangers 10 and 32, the overhead is merged in line 34 and has a temperature in the range of from about −140°F. to about −170°F., depending on the composition of the overhead from drum 24 and the feed composition to the plant and preferably at about −160°F. The material in line 34 is then combined with the fractionator overhead as hereinafter explained which has been condensed and pumped from about 320 psia to 380 psia. After combining the effluent streams from exchangers 8, 10 and 32, resulting in a combined stream pressure in the range of 350 to 450 psia and more preferably about 380 psia and in a temperature in the range of −140°F. to −180°F., or about 10°F. below the stream bubble point, depending on the stream composition, the material in line 38 is pumped up to a pressure in a range of 900 to 1100 psia and preferably about 1000 psia by pump 40. This high pressure stream is then used to make possible the condensation of the overhead vapors from drum 24 in exchanger 32. Upon exit from exchanger 32, they are conducted via the line 44 through heat exchanger 46, which exchanger serves to vaporize and superheat the methane rich product gas so that when combined with the reformed gas in line 49 gives a suitable pipeline temperature in the range of 32°F. to 104°F. and preferably 50°F. Upon exiting from exchanger 46 via the line 47 the material is at about 1000 psia and at about 5°F. according to the preferred embodiment. This material has a composition as indicated in Table III.

TABLE III

Constituent	Mole %
C_1	70 to 80
C_2	20 to 25
C_3	0 to 5
C_4+	0 to .5

The material in line 47, which when combined with the reformed product in line 49, is at suitable pipeline distribution conditions and is fed from the line 51 to a suitable distribution network (not shown).

Returning once again to drum 24, the bottom products leaving drum 24 via the line 48 and having a temperature of approximately −58°F., are combined with part of the bottoms from drum 52. The combined stream serves as a heat transfer media in a pump-around circuit. The combined stream in line 50, having a temperature of approximately 50°F., is fed to drum 52. The feed to drum 52 has a composition in the ranges indicated in Table IV below:

TABLE IV

Constituent	Mole %
C_1	18 to 25
C_2	25 to 35
C_3	18 to 25
C_4	9 to 15
C_5 and C_5+	2 to 5

Drum 52 is operated at a pressure of from about 300 to about 450 psia and preferably about 380 psia. A portion of the bottoms leaving drum 52 which is called the pump-around is conducted via the line 88 through exchanger 90, wherein it is heated by passing it in heat exchange with a hot reformate stream entering exchanger 90 via the line 82 and exiting exchanger 90 via the line 84. Upon exit from exchanger 90, said portion of the bottoms from drum 52 is conducted through exchanger 46, where the methane rich gas is vaporized. Upon leaving exchanger 46, the pump-around is conducted via line 92 through exchanger 20, where it serves to further heat the incoming LNG feed. Upon exit from exchanger 20, this bottom fraction is combined with the bottoms from drum 24 and introduced via the line 50 back into drum 52.

The remaining portion of the bottoms from drum 52 are passed through line 56 into line 54 where they are combined with the products leaving the top of drum 52 and this recombined stream is then fed via the line 58 into a fractionating column 60. Tower 60 effects the separation of C_3− and C_4+ constituents. The C_3− material leaves the tower 60 at the top of the tower through line 62 and heat exchanger 16 to the drum 64 where a portion of it is withdrawn

through line 66 and pumped by pump 68 via line 70 back into the tower 60. The C_3+ material leaves the bottom of the tower via the line 74 and enters reboiler 76 where it is heated by any conventional means. A portion of the material entering reboiler 76 is re-introduced into the bottom of the tower via the line 78. The remaining portion of the bottoms from column 60 leaves reboiler 76 via the line 79 and is then fed to a reforming complex indicated as 80. The material entering reforming complex 80 has a composition as indicated in Table V below.

TABLE V

Constituent	Mole %
C_1	0
C_2	0
C_3	60 to 70
C_4	20 to 30
Others	5 to 15

In the reforming operation this composition is converted so that the reformate will have a composition as indicated in Table VI.

TABLE VI

Constituent	Mole %
CO_2	3 to 7
CO	1 to 2
H_2	20 to 30
CH_4	60 to 70

A great deal of water, comprising about 50 percent of the molar flow, will also be present. This water is removed (in suitable apparatus not shown) after the reformate gas is heat exchanged with the portion of the bottoms from drum 52 as hereinbefore discussed. After this heat exchange, the reformate gas is ultimately fed via the line 86 to a compressor 87 where its pressure is raised to approximately 1000 psia. The material leaving compressor 87 is then fed via the line 49 into the product gas line 51.

EXAMPLE

Starting with a typical LNG feedstock composed of:

TABLE VII

Constituent	Mole %
C_1	68
C_2	19
C_3	10
C_4	2
C_5	1

and operating in the aforesaid preferred temperature and pressure ranges, the following table indicates the approximate temperatures, pressures and stream compositions present at various locations in the depicted process. These locations are designated by referring to their assigned reference numerals appearing in the figure.

TABLE VIII

Location	Temperature (°F)	Pressure (Psia)	Typical Stream Composition (Mole Percent)									
			C_1	C_2	C_3	C_4	C_5	C_6	CO_2	N_2	CO	H_2
Line 6	−250	450	68	19	10	2	—	1	—	—	—	—
Line 14	−85	425	68	19	10	2	—	1	—	—	—	—
Line 22	−58	400	68	19	10	2	—	1	—	—	—	—
Line 26	−58	400	85	13	2	—	—	—	—	—	—	—
Line 48	−58	400	25	35	26.5	11.5	1.5	.5	—	—	—	—
Line 58	50	380	25	35	26.5	11.5	1.5	.5	—	—	—	—
Line 62	−15	355	36	55	9	—	—	—	—	—	—	—
Line 79	160	360	—	—	57.5	31.5	10	1	—	—	—	—
Line 51	50	1000	74.2	11.8	1.7	.17	.005	—	1.4	—	.92	9.6

WHAT WE CLAIM IS:—

1. A process for regasifying a feed of liquefied gas mixture wherein the liquefied gas mixture is regasified in part, the non-regasified mixture being subject to a further processing operation comprising the following steps:

pressurizing and heating said liquefied gas feed;

flashing said feed into a first flashing drum;
passing the bottoms from said first drum to a second flashing drum and recovering a regasified overhead stream from the first flashing drum;
drawing off a portion of the stream from the bottom of said second drum and recovering any regasified overhead stream from the second drum;
heating said portion by use of a process stream from said further processing operation;
passing said heated portion in heat exchange with the incoming liquefied gas feed to said first drum; and then
combining said portion with said bottoms from said first drum and passing the resulting combined stream into said second drum.

2. The process according to claim 1 wherein the original heating is partially accomplished by utilizing heat from the materials leaving the top of said first flashing drum.

3. The process according to claim 1 or claim 2 wherein said first drum is operated at a pressure in the range of from 300 to 500 psia and said second drum is operated in a range of from 300 to 450 psia.

4. The process according to any preceding claim wherein said liquefied gas mixture is liquefied natural gas and said process stream from said further processing operation is a hot reformate gas stream obtained by reforming heavy ends of said natural gas obtained by fractionation of the bottoms from said first drum.

5. The process according to claim 4 characterized in that the original heating is accomplished by passing entering natural gas feed in heat exchange relationship with process streams resulting from the fractionation of said natural gas feed.

6. The process according to any of the preceding claims in which the overhead from said first flashing drum is passed in heat exchange relationship with the entering natural gas feed.

7. The process according to claim 6 wherein vapors from the top of said second drum and the remaining part of the bottoms from said second drum are combined and fractionated in a C_3 and heavier cut and a C_2 and lighter cut, with the C_2 and lighter cut being passed in heat exchange with said pressurized feed.

8. The process according to claim 7 wherein the overhead from said first drum is split into a first sidestream and a second sidestream, said first sidestream being passed in heat exchange relationship with said incoming feed and said second sidestream being passed in heat exchange relationship with vapors from said C_2 and lighter cut.

9. The process of regasifying and further processing a liquefied gas substantially as hereinbefore described and with reference to the accompanying drawing.

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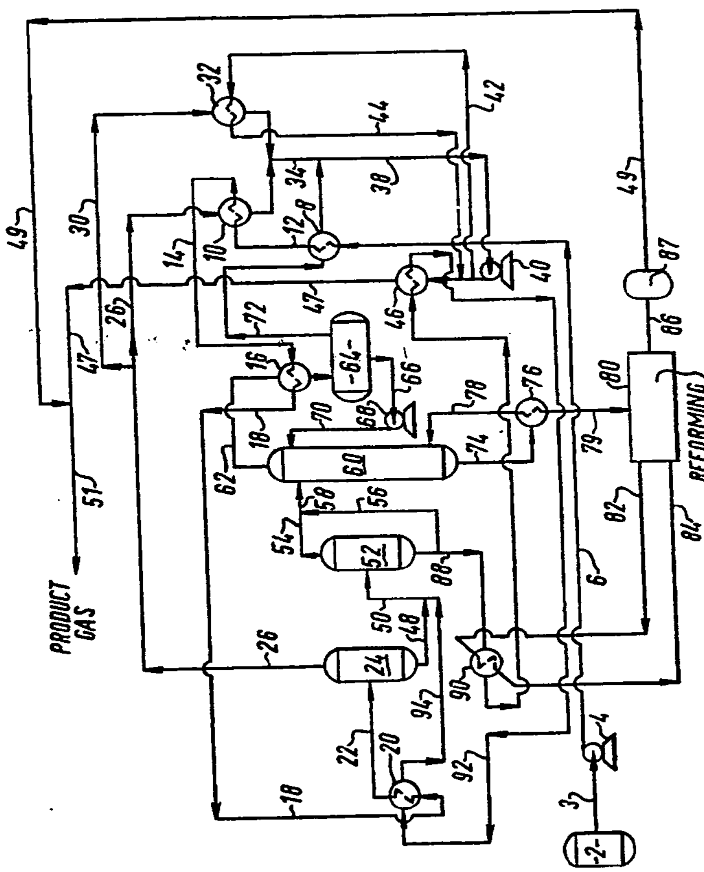
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